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Road Salt Use in the United States

Under many snow and ice conditions, the use of deicing chemicals is necessary to maintain clear pavements. In terms of both time and budget, common salt, or sodium chloride, is widely regarded as the most effective means of deicing highways. Salt is by far the most commonly used deicing chemical in the United States; it is spread at a rate of approximately 10 million tons per year.

This chapter provides general background information on the use of road salt, including trends in usage, application and storage practices, use by region and jurisdictional level, and annual spending on salting operations. The chapter concludes with a brief discussion of some of the benefits of deicing and efforts being made by highway agencies to manage their salting programs.

TRENDS IN ROAD SALT USE

The use of road salt has paralleled changes in the size and importance of the nation's highway system. Before the 1940s, highway departments relied mostly on plowing and abrasives (e.g., sand and cinders) to keep roadways open after winter storms. Salt was used primarily as an additive to prevent freezing of sandpiles. During the winter of 1941–1942, New Hampshire became the first state to adopt a general policy of using salt, although a total of only 5,000 tons of salt was spread on the nation's highways that winter (TRB 1974, 2).

After World War II, as the expanding highway system became essential to the public and the national economy, road salt use began to soar. The bare-pavement concept, under which motorists could expect snow- and ice-free pavements shortly after storms, soon became a policy in most cities and their suburbs. As a result, salt use doubled every 5 years during the 1950s and 1960s, growing from 1 million tons in 1955 to nearly 10 million tons less than 15 years later (Figure 2-1).

Road salt use has leveled off during the past 20 years. Whereas salt use increased rapidly during the 1950s and 1960s because it was replacing abrasives, by the 1970s this conversion was nearly complete. Also, at about this time, many of salt's adverse effects were becoming well known, causing many highway agencies to reevaluate their salting practices. Through practical experience and with guidance from government and industry, many highway agencies started managing their salting programs, for example, by calibrating spreading equipment and establishing formal salt use policies. Partly because of these changes, annual salt use has fluctuated from 8 million to 12 million tons during the past 20 years, with year-to-year fluctuations depending mainly on winter conditions.

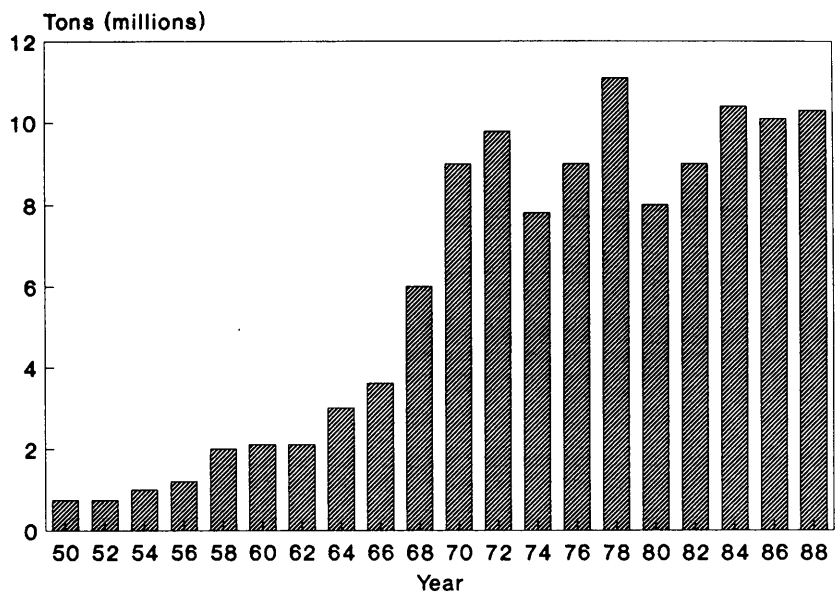

FIGURE 2-1 Trends in highway salt use, 1950–1988 (source: Salt Institute).

SALT APPLICATION AND STORAGE

Early in the century, when salt was used selectively on busy city streets, it was often shoveled from the back of trucks. As its use grew, innovations were made in salting equipment and practices. During the 1950s and 1960s, spinning disks and rollers extending the width of the truck were introduced to allow spreading over a wide path. Later, many highway agencies learned to spread salt more efficiently by windrowing it in a narrow line to produce concentrated brines that flowed under the ice to break the pavement-ice bond. Other methods of applying salt include the direct dispensing of salt solution from trucks equipped with a tank and nozzle and the use of "prewetted" salt dampened with water or liquid calcium chloride. Because prewetted salt adheres well to the pavement (reducing wind and traffic scatter) and acts faster than dry salt (by dissolving faster), less deicing chemical is required.

Salt Application Rates

Salt melts ice by depressing the freezing point of water.[1] The addition of salt to water lowers the freezing point of the solution until the salt concentration reaches about 25 percent. This threshold concentration marks the eutectic point, at which the freezing temperature of the solution can no longer be lowered, and the addition of more salt has no additional ice-melting effect. The eutectic temperature for salt solution is $-21°C$ ($-6°F$). Under field conditions, however, ice melting is much too slow near the eutectic temperature to be of practical significance. At pavement temperatures below $-12°C$ (10°F), sodium chloride is seldom used, and highway agencies rely more on sanding or salt mixed with calcium chloride, which remains effective in cold conditions.

As a practical matter, at pavement temperatures above $-12°C$ (10°F), the amount of salt needed for highway deicing is usually less than the theoretical amount necessary to melt all the ice. If applied properly, small amounts of salt usually produce partial melting and flowing brines that break the bond between pavement and ice and thereby allow accumulations to be removed by the action of traffic or plowing (TRB 1974). Usually, highway maintenance engineers are given flexibility to determine salt application rates on the basis of their judgment of weather and roadway conditions. Critical bridges

and highways, such as multilane freeways, are typically treated most intensely, through higher application rates and more frequent treatment. Lower-priority streets and secondary roads are often left untreated for longer periods, or not treated at all (see Figure 2-2).

Official salt application rates for several states are listed in Table 2-1. Rates vary from state to state, although most are between 200 and 400 lb/lane-mi on high-priority highways. On medium-priority roads, coverage tends to be reduced or eliminated at night, and salt is mixed with abrasives to reduce salt use by at least 25 percent. These policies generally do not limit the frequency of application. As might be expected, northern states tend to have the highest annual loadings of salt because of their higher application frequencies. New York, Massachusetts, Michigan, New Hampshire, and Vermont report the highest annual salt loadings. Each averages more than 10 tons/lane-mi on state-maintained highways (Table 2-2).

Municipal highway agencies were not surveyed in this study. They are among the most generous users of road salt because of the emphasis placed on clearing bus lanes and commuter routes (TRB 1974). Toll authorities are also heavy salt users, because they are selling a service and do not wish to lose customers by allowing hazardous driving conditions or delays.

Storage

Salt storage facilities are usually located at highway maintenance yards as well as at other intermediate points along highways (see Figure 2-3). The location, size, and number of storage facilities often depend on the priority of the roads being treated and the incidence of special features, such as bridges and intersections that require more frequent salting.

When stored outside and exposed to precipitation, salt solution may run off and leach into surrounding soils and groundwater unless properly covered and drained. Accordingly, highway agencies increasingly store salt on impervious pads and in leakproof shelters, such as sheds, barns, or "beehive" domes that correspond to the salt pile's angle of repose. These buildings, which often cost upwards of $100,000 to build, can provide storage for more than 1,000 tons of salt. In recent years, some highway agencies have introduced high-capacity silos for gravity loading. Silos reduce the potential for spillage during handling while protecting the salt from exposure to moisture and humidity.

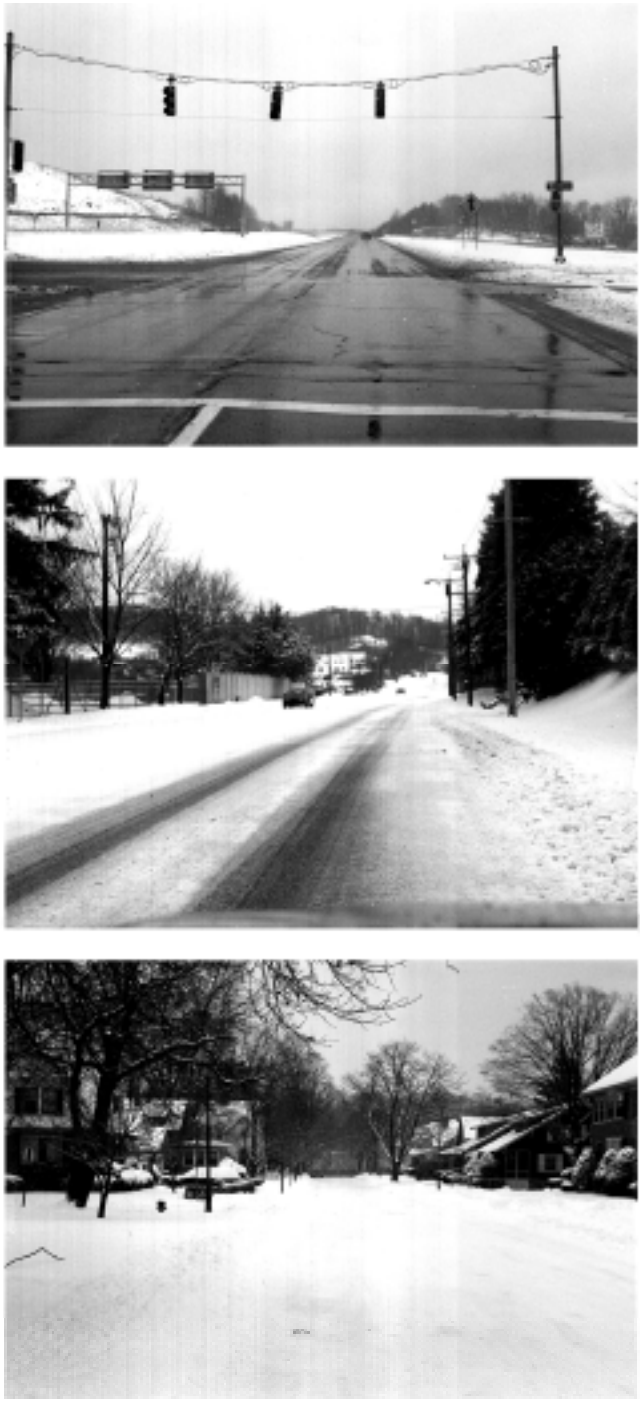

FIGURE 2-2 *Top:* Primary highway. *Middle:* Secondary highway. *Bottom:* Residential street.

TABLE 2-1 OFFICIAL SALT USE POLICIES IN VARIOUS STATES

Region and State	Summary of General Policy
New England	
Connecticut	Salt applied at 215 lb/lane-mi on multilane roads; no more than 150 lb/lane-mi on two-lane state highways
Massachusetts	Salt applied at less than 300 lb/lane-mi on state highways
New Hampshire	Salt application guideline of 250 to 300 lb/lane-mi on state highways
Middle Atlantic	
Maryland	Salt application guideline of 300 to 500 lb/lane-mi on state highways
West Virginia	Salt application guideline of 100 to 250 lb/lane-mi, usually mixed with abrasives, except in cities
Great Lakes	
Michigan	Salt applied at 225 lb/lane-mi on primary highways. Salt and sand mixtures used on lower-priority roads, depending on storm temperature and severity
Ohio	Salt applied at 200 to 300 lb/lane-mi on Interstate and primary highways; 100 to 200 lb/lane-mi, with abrasives on secondary roads; no more than 100 to 200 lb/lane-mi on low-priority roads
Wisconsin	Salt application rates of 100 to 300 lb/lane-mi recommended; additional salt use restrictions related to pavement temperature in place
Plains	
Iowa	Salt applied at 150 lb/lane-mi (mixed with sand) on Interstates and other arterials; 100 lb/lane-mi on collectors; no salt used on local roads
Kansas	Salt applied at 100 to 250 lb/lane-mi (mixed with sand) on Interstates, freeways, and other roads with 2,500+ ADT; less on roads with 750 to 2,500 ADT; no salt used on roads with < 750 ADT
West	
Colorado	Salt only with abrasives; rates not defined
California	Salt applied at 500 lb/lane-mi on some mountain highways

NOTE: Although policies often identify an ideal salt application rate for equipment calibration, they seldom regulate the timing and frequency of applications. Application timing and frequency are typically determined by the maintenance engineer in charge during the storm. Data in the table are from states that responded to relevant questions in survey. ADT = average daily traffic.
SOURCE: TRB survey of state highway agencies.

SALT USE BY JURISDICTION AND REGION

Nationwide, there are more than 3.8 million mi of public highway and streets. Except for minor amounts of mileage on federal lands, practically all of these roads are maintained by state and local high-

TABLE 2-2 AVERAGE ANNUAL SALT LOADINGS ON STATE HIGHWAYS WHERE SALT IS NORMALLY APPLIED

Region and State	Average Annual Loading (tons/lane-mile)
New England	
Maine	8.0
Massachusetts	19.4
New Hampshire	16.4
Vermont	17.1
Middle Atlantic	
Delaware	9.0
Maryland	7.1
New Jersey	6.7
New York	16.6
Virginia	3.0
West Virginia	6.3
Great Lakes	
Illinois	6.6
Indiana	9.0
Michigan	12.9
Ohio	9.1
Wisconsin	9.2
Plains	
Iowa	3.8
Minnesota	5.0
Missouri	1.0
Nebraska	1.5
Oklahoma	1.5
South Dakota	1.0
Mountain and West	
Alaska	1.2
California	3.0
Idaho	0.3
Nevada	1.9
New Mexico	0.5

NOTE: Data are from only those states that responded to relevant questions in survey.
SOURCE: TRB survey of state highway agencies.

way agencies. As the data in Table 2-3 indicate, state highway agencies (including toll authorities) administer about 20 percent of this mileage, including all Interstates and virtually all other primary highways. Local governments (counties, cities, and towns) have jurisdiction over about three-quarters of all mileage, although a large share consists of low-volume secondary roads and residential streets.

Figure 2-4 shows the share of total salt usage by state, toll, county, and municipal highway agencies, derived from Salt Institute data and

FIGURE 2-3 Highway maintenance yard. *Top:* Salt hopper and spreader truck. *Bottom:* Salt storage shed.

the survey of state highway agencies conducted for this study. Because of the heavy traffic demands on primary highways, states and toll authorities are especially heavy users of salt, accounting for about one-half of all the salt used nationally. The next largest users are municipal agencies—especially large cities—which account for about 35 percent of salt use. County highway agencies account for the remaining 15 percent. Because counties are often responsible for

TABLE 2-3 ROAD MILEAGE CLASSIFIED BY FEDERAL-AID SYSTEM AND JURISDICTION (FHWA 1989, 114–116)

Jurisdiction	Federal-Aid System Mileage			Non-Federal-Aid Mileage	Total Mileage	Percentage
	Interstate and Other Primary	Secondary (Rural)	Urban			
State and toll	300,455	196,503	33,996	269,297	800,251	21
County	961	193,383	27,430	1,451,976	1,673,750	43
Municipal	1,560	9,269	85,534	1,116,068	1,212,431	31
Federal	470	926	75	182,888	184,359	5
Total	303,446	400,081	147,035	3,020,229	3,870,791	100

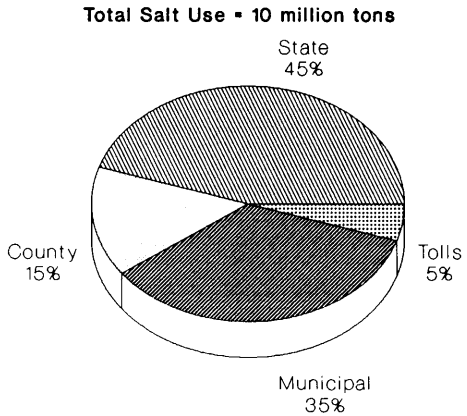

FIGURE 2-4 Salt use by jurisdiction (source: state survey and Salt Institute).

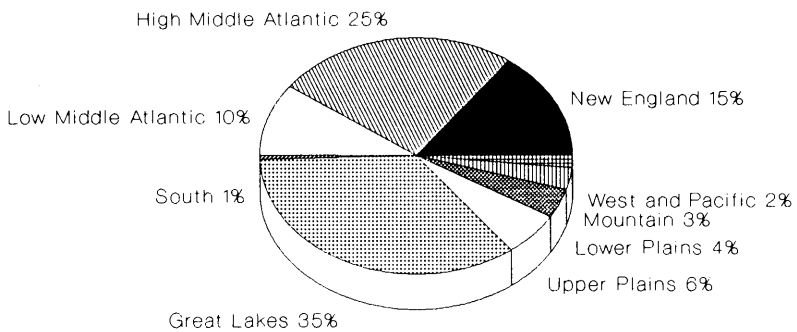

FIGURE 2-5 Salt use by region (source: state survey and Salt Institute).

clearing many miles of rural secondary roads, they frequently use less salt per lane-mile than cities and depend more on plowing and sanding.

As shown in Figure 2-5, most salt is used by states in New England, the Great Lakes, and the Middle Atlantic regions (as defined by TRB in Figure 2-6), which together account for more than 85 percent of all road salt used nationally. By comparison, states in the Plains and Mountain regions account for only 13 percent of total salt use, because they have lighter traffic demands and longer periods of cold temperatures during which salt is ineffective. These states rely more on sanding and plowing for snow and ice control. States in the Pacific and Southern regions use little road salt except at higher elevations.

FIGURE 2-6 Definition of regions.

SPENDING ON ROAD SALT

The average price of salt is approximately $30 per ton delivered. Prices can vary from $15 to $40 per ton, depending on proximity to the source (e.g., salt mines) and shipping facilities. In the survey conducted for this study, state highway agencies were asked to estimate the portion of their winter maintenance budgets normally dedicated to purchasing salt and other deicing chemicals. Responses varied among states, depending on their winter conditions and demands for clear pavement. Collectively, state highway agencies spend about $750 million per year on all aspects of winter maintenance (Figure 2-7). On the average, 20 percent of this spending, or $150 million, is for the purchase of deicing chemicals (Figure 2-7).

The existence of thousands of county and municipal highway agencies makes it difficult to estimate salting expenditures at this jurisdictional level. Nevertheless, because municipalities and counties use about one-half of all the road salt applied each winter, these expenditures are likely to be significant. If local highway agencies collectively spend as much on salt purchases as states—which is likely because each applies about the same amount of salt—total state and local spending on salt purchases is approximately $300 million per year ($150 million by states + $150 million by counties and municipalities).

This figure represents only a portion of total spending on salting operations. Related expenditures include storage, handling, and

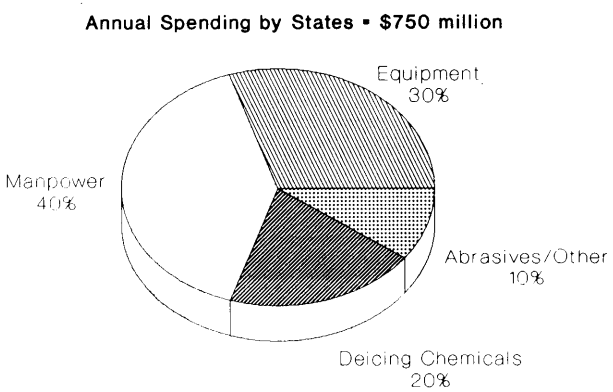

FIGURE 2-7 State spending on snow and ice control by type of expenditure (source: state survey and Salt Institute).

spreading. The New York State Department of Transportation, which accounts for about 10 percent of state-level spending on road salt, estimates that these other salt-related costs (e.g., equipment and labor for spreading, handling, and storage) average about $25 per ton of salt applied (personal communication, Assistant Commissioner for Operations of the New York State Department of Transportation). Hence, a rough national estimate of these costs can be developed by multiplying $25 by the 10 million tons of salt applied each winter in the United States. The result is $250 million per year.

These estimates of salt purchase and application costs suggest that total annual spending on road salting is slightly more than $500 million and represents about one-third of the $1.5 billion spent on winter maintenance activities each year.

DEICING BENEFITS

Among the benefits of deicing are fewer disruptions in trucking and other commercial traffic, smaller losses in work force productivity because of absent and tardy workers, and uninterrupted provision of emergency services. Presumably, deicing also improves highway safety, although no studies have demonstrated this effect unequivocally because of the many interrelated factors found in accident statistics (TRB 1974, 8).

These benefits, which are difficult to quantify, are widely acknowledged to be valuable to society. Hence, changes in deicing policies

or practices that threaten to reduce these benefits often arouse public concern and opposition.

MANAGING ROAD SALT

Whereas salt is an effective snow- and ice-control tool, its limitations require careful management. Recognizing both the importance of highway deicing and the adverse side effects of salt, many highway agencies have tried to control salt use without sacrificing deicing effectiveness. Management improvements have focused primarily on reducing excessive salt use or waste, for example, through personnel training, more accurate and timely weather information, and better spreading equipment and techniques.

In some states computerized inventory methods that monitor salt usage by district and stockpile, and sometimes by truck, have been implemented. Combined with proper operator and supervisor training, monitoring creates incentives to eliminate unnecessary salting. Likewise, improvements in spreading equipment and weather forecasting have helped some highway agencies control salt use. For example, during the 1960s and 1970s, automatic, ground-oriented spreader controls were introduced to regulate salt discharge according to truck speed. Recently, some state and municipal highway agencies have started to contract with private weather services for storm advisories. The prediction of snow and ice conditions can shorten the lead time required to start salting operations and, therefore, reduce the amount of salt used unnecessarily when storm conditions do not develop as originally expected.

SUMMARY

Salt and other chemicals are important for highway snow and ice control. Approximately 10 million tons of salt is spread on the nation's highways each winter. Most road salt is applied in the Northeast and Midwest. Salting is heaviest on high-volume highways and city streets, where traffic demands are greatest; accordingly, many state and municipal highway agencies are heavy users of salt.

The price of road salt averages $30 per ton. Each year, state and local highway agencies spend about $300 million on salt purchases and another $250 million on storage, handling, and application. To control expenditures on salting and reduce its adverse side effects, many highway agencies are reevaluating the way they use salt. Better

management practices, equipment, and spreading techniques have improved both the effectiveness and the efficiency of many salting programs.

NOTE

1. When salt dissolves in water, the freezing point is depressed in proportion to the concentration of ions in solution. Because sodium chloride is very soluble in water and yields a large number of ions per unit weight, it is especially effective as a freezing point depressant, or ice melter.

REFERENCES

ABBREVIATIONS

FHWA	Federal Highway Administration
TRB	Transportation Research Board

FHWA. 1989. *Highway Statistics 1988.* U.S. Department of Transportation.

TRB. 1974. *NCHRP Synthesis of Highway Practice 24: Minimizing Deicing Chemical Use.* National Research Council, Washington, D.C.